Dileptons in PHENIX

Deepali Sharma

for the PHENIX Collaboration

Stony Brook University

12th June, 2012

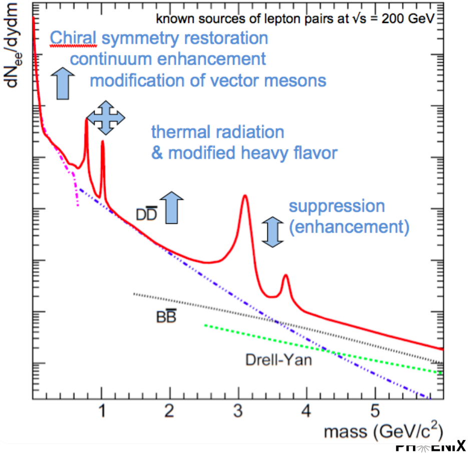
Outline

Dilepton mass spectrum

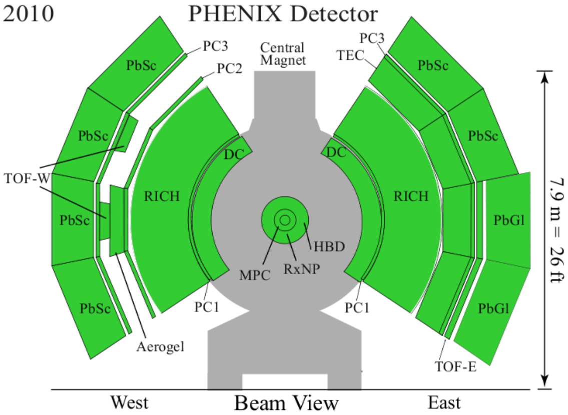
Diverse physics signal

- Thermal radiation:
  QGP ($q\bar{q} \rightarrow \gamma^* \rightarrow e^+e^-$)
  HG ($\pi^+\pi^- \rightarrow \rho \rightarrow e^+e^-$)
- light vector mesons and low-mass continuum: sensitive to chiral symmetry restoration that will appear as mass shifts, broadening or excess yield.
- open heavy flavor: thermal radiation and medium modification.
- quarkonia: suppression/enhancement of quarkonium production reveals critical features of the medium.

Modifications to the dilepton spectrum due to the QCD phase transition



PHENIX Central arms Acceptance: -0.35$< \eta <$0.35, 2$\times$90° in φ



Collision sysytems: **p+p, d+Au, Cu+Cu, Au+Au**

- Vertex: **BBC**
- Tracking: **DC/PC1**
- $p_e > 0.2$ GeV/c;

Electron identification based on:

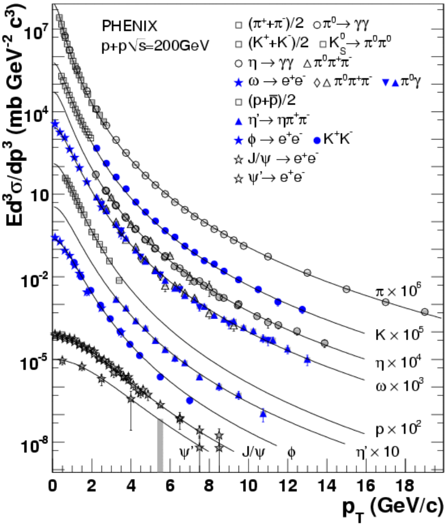
- **RICH** (Ring Imaging Čerenkov detector) (e/π rejection >1000)
- **EMCal** (Electromagnetic Calorimeter) (E-p matching, e/π rejection $\sim$ 10)

Cocktail of hadronic sources

- Hadron decays
  - Fit the $\pi^{\pm}$ and π^0 data for a given collision system

$$E\frac{d^3\sigma}{dp^3} = \frac{A}{(e^{-(ap_T+bp_T^2)} + p_T/p_0)^n}$$

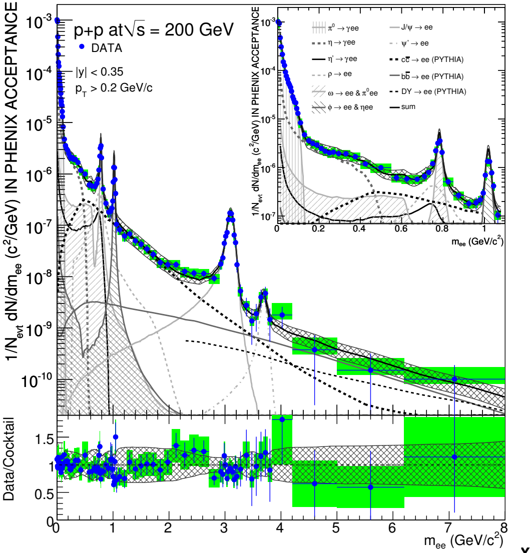
  - For all other mesons, use m_T scaling: $p_T \to \sqrt{p_T^2 - m_{\pi^0}^2 + m_{hadron}^2}$ and fix normalization using the existing data where available.
- Charm, Bottom, Drell Yan from PYTHIA
  - For a given collision system use $N_{coll} \times \sigma_{cc} = 567 \pm 57 \pm 193$ measured in $p + p$ from single electrons.
- Put the ideal PHENIX acceptance filter.



What PHENIX has measured so far ....

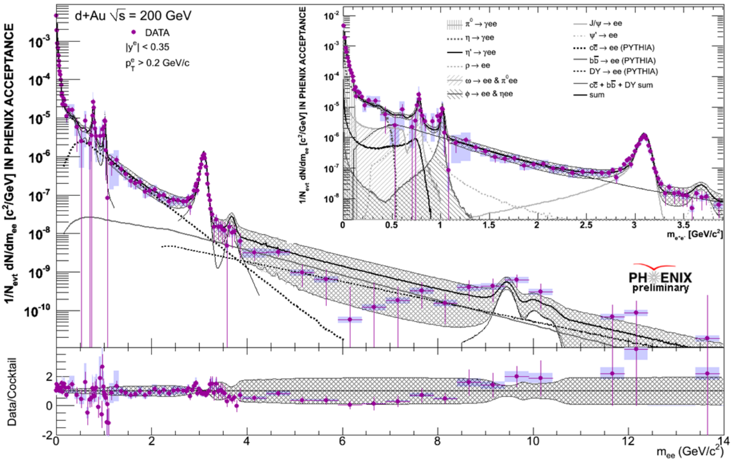
- Inclusive mass spectrum of e^+e^- measured from $m = 0$ to $m = 8$ GeV/c^2.
- Very well understood in terms of
  - hadron cocktail at low masses.
  - heavy Flavor + DY at high masses
- **Charm: integration after cocktail subtraction;** $\sigma_{c\bar{c}} = 544 \pm 39(stat) \pm 142(sys) \pm 200(model)\mu b$ *(consistent with PHENIX single electron measurement)*
- **Simultaneous fit of charm and bottom;**
  - $\sigma_{c\bar{c}} = 518 \pm 47(stat) \pm 135(sys) \pm 190(model)\mu b$
  - $\sigma_{b\bar{b}} = 3.9 \pm 2.4(stat) \pm^{3}_{-2}(sys)\mu b$

PLB 670, 313 (2009)

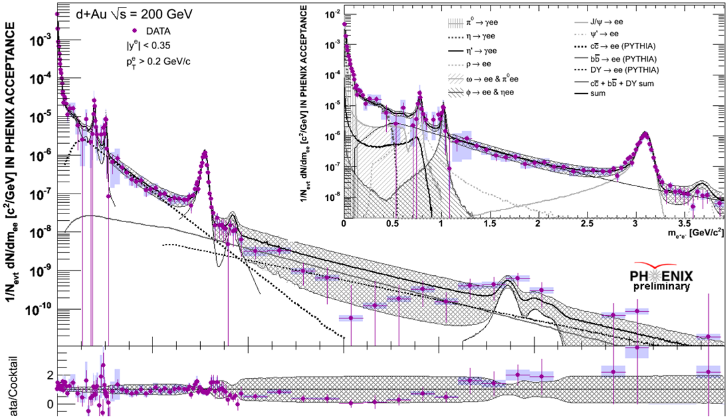


Stony Brook University

Dileptons in PHENIX: d + Au collisions (Minimum bias)



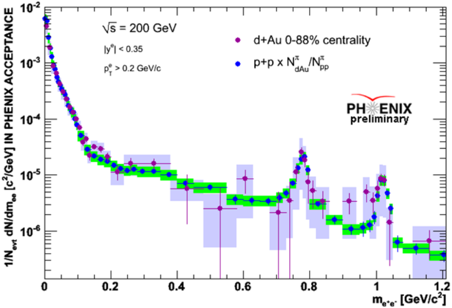
Dileptons in PHENIX: $d + Au$ collisions (Minimum bias)



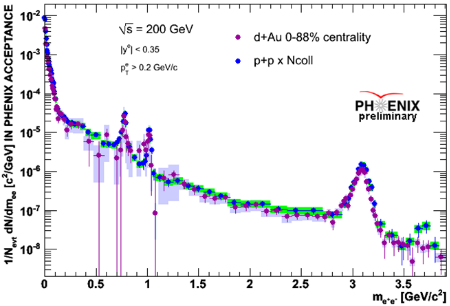
- Consistent with the expected cocktail of known sources both in low-mass and intermediate mass region.
- large mass range coverage $0 - 14\ GeV/c^2$.
- Data will constrain known sources with better precison, e.g. bottom cross-section.

Comparison of $d + Au$ to scaled $p + p$ data

Low mass region



Intermediate mass region

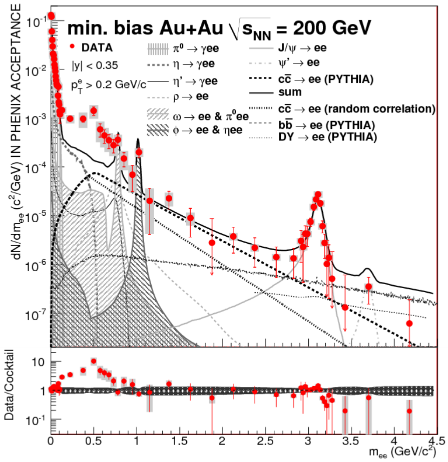


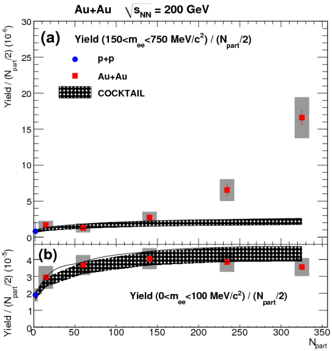
- No excess in LMR.
- $d + Au$ consistent with scaled $p + p$.

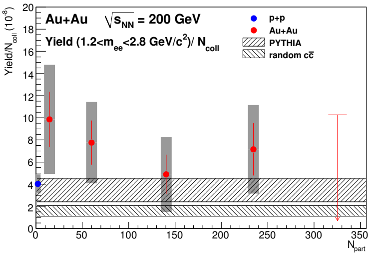
- No excess in IMR.
- $d + Au$ consistent with scaled $p + p$.
- J/ψ suprresion ~ 0.75 observed.

Dileptons in PHENIX: Au + Au collisions

Au + *Au* **(PRC 79, 81 034911(2010))**

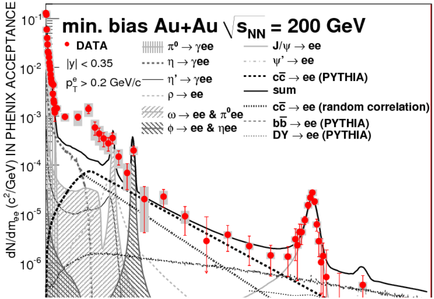


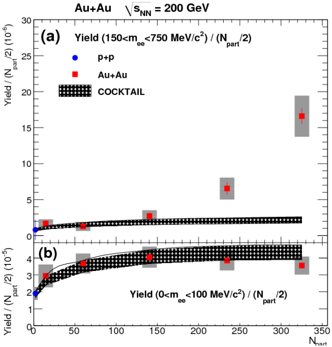




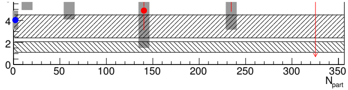
Dileptons in PHENIX: Au + Au collisions

Au + *Au* **(PRC 79, 81 034911(2010))**





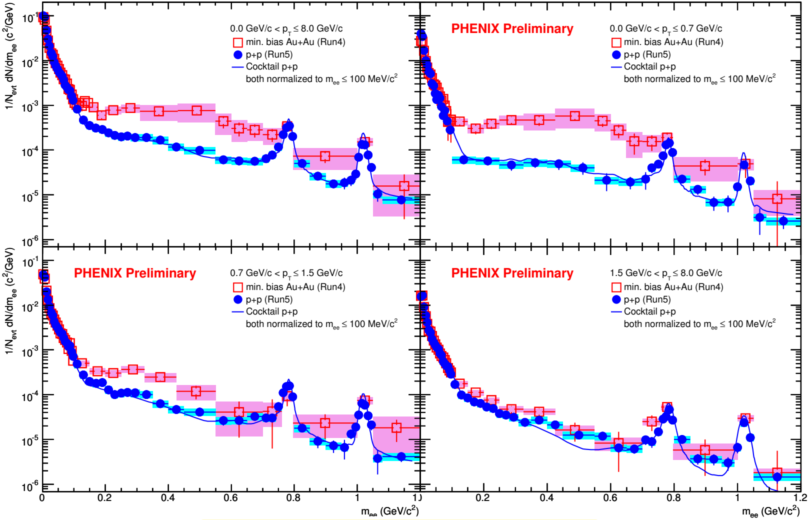
- Strong enhancement of e^+e^- pairs at low masses:
  $(4.7 \pm 0.4(stat) \pm 1.5(sys) \pm 0.9(model)\mu b$ $(0.15 \leq\ m_{e^+e^-}\ \leq 0.75\text{GeV}c^2)$
- Characteristic properties:
  - Enhancement down to very low masses
  - Enhancement concentrated in central collisions
  - No enhancement in the IMR



Stony Brook University

PHENIX

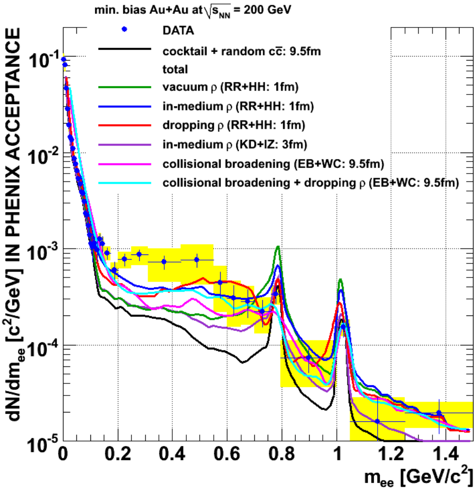
Low mass region: evolution with p_T



Enhancement mostly at low p_T

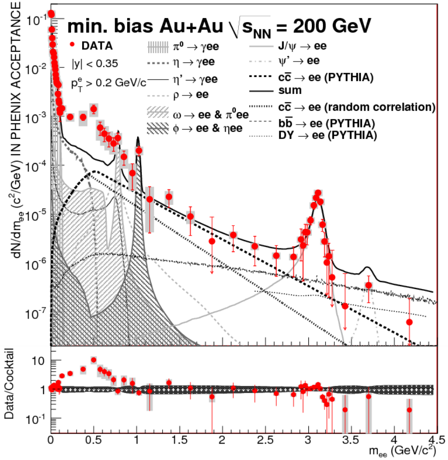
Stony Brook University

Comparison to theoretical models (Au + Au)

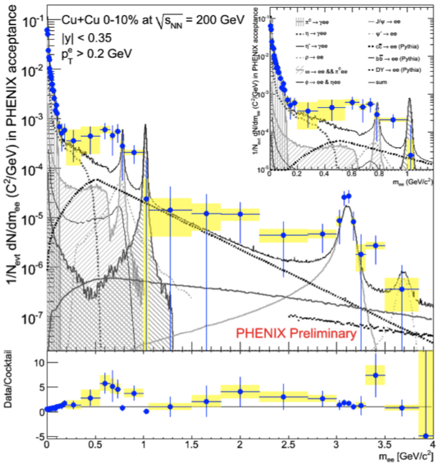


All models and groups that successfully described the SPS data fail in describing the PHENIX results

$Au + Au$ (PRC 79, 81 034911(2010))
N_{part} = 109



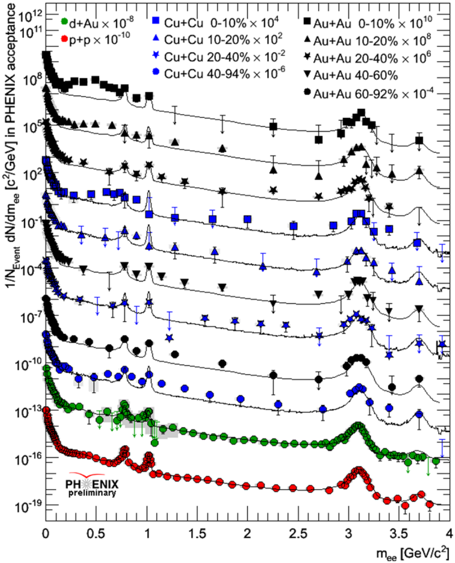
$Cu + Cu$ (0-10%)
N_{part} = 98

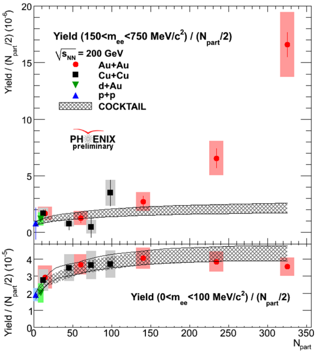


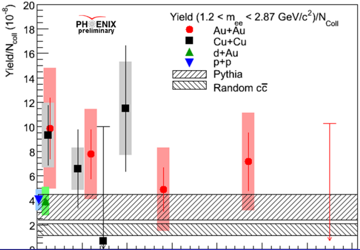
PHENIX

Centrality dependence of yields across different systems

ordered by N_{coll}

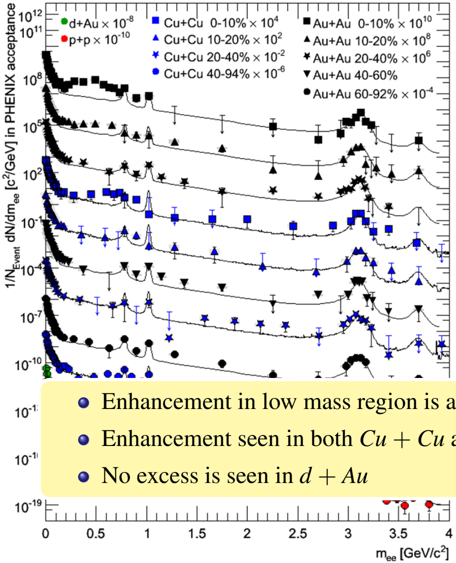


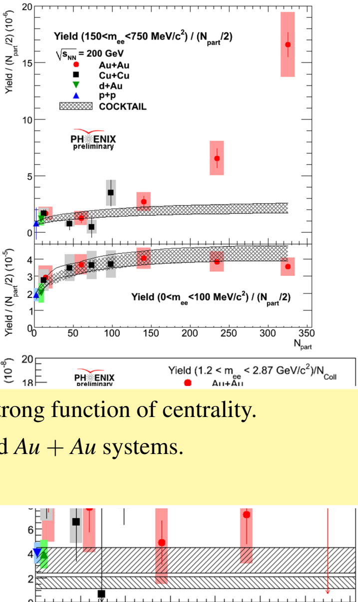




Stony Brook University

PHENIX

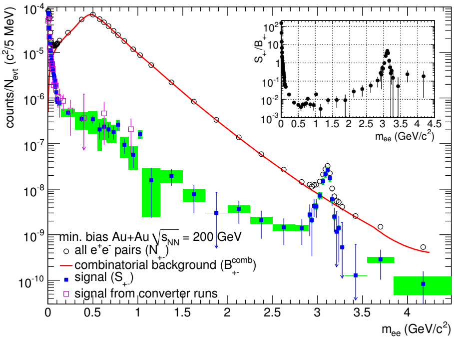




- Enhancement in low mass region is a strong function of centrality.
- Enhancement seen in both $Cu + Cu$ and $Au + Au$ systems.
- No excess is seen in $d + Au$

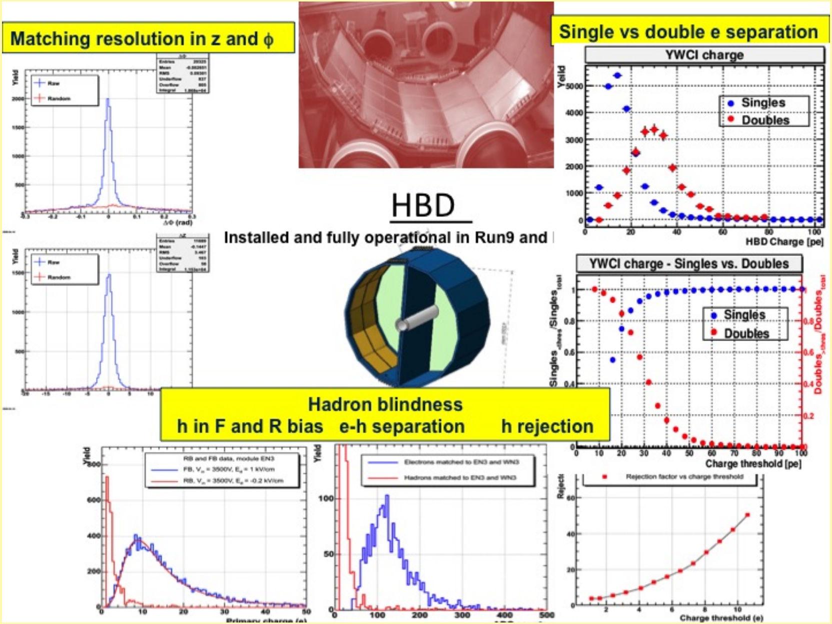
Near future

The future: Hadron Blind Detector



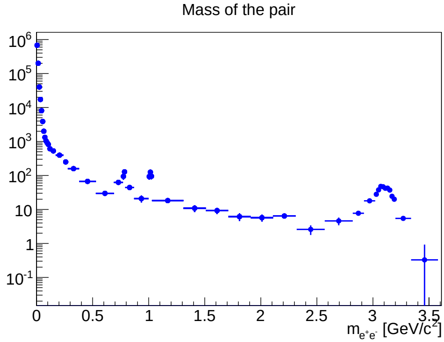
- The present PHENIX results suffer from large systematic uncertainties.
- The S/B ratio in $Au + Au$ (Run4) is $\sim$ 1/200 at mass $m_{e^+e^-} \approx 500$ MeV/^{2}.
- A Hadron Blind Detector was installed in 2009 to improve measurements in the LMR by reducing the combinatorial background.
  - use opening angle cut to reject Dalitz decays and conversion pairs

The future: Hadron Blind Detector

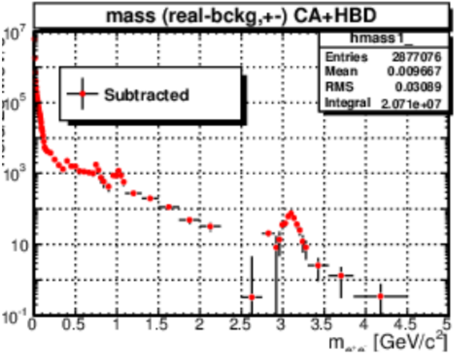


Present status of analysis with HBD

$p+p$



$Au+Au$ **(40-100%)**



- Uncorrected mass spectra in $p+p$ and $Au+Au$ with HBD
- Both analyses are expected to finish by QM

Summary

$p + p$ and $d + Au$

- Both $p + p$ and $d + Au$ results are well described by the cocktail.
- No cold matter effects are seen in $d + Au$.

$Au + Au$ and $Cu + Cu$

- The low-mass region in $Au + Au$ shows an enhancement above the cocktail expectations: $4.7 \pm 0.4(stat) \pm 1.5(sys) \pm 0.9(model)$
- Theory models fail to describe the data.
- Enhancement is seen in $Cu + Cu$ also.

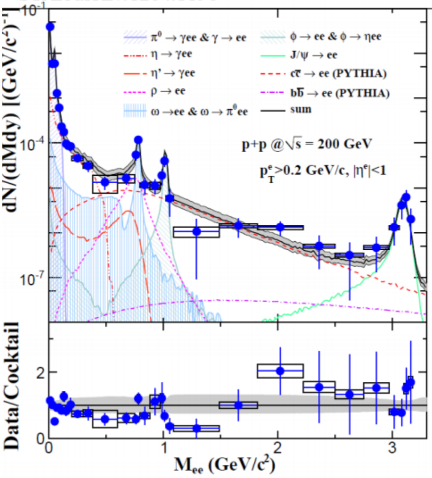
Future: HBD analysis

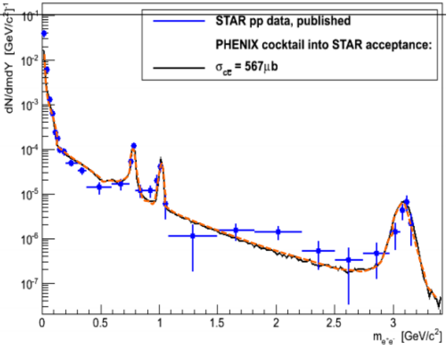
- Analysis of the data with HBD will provide a better precision measurement for the LMR. Results of this analysis are expected soon.

Back-ups

Star $p + p$ dilepton data

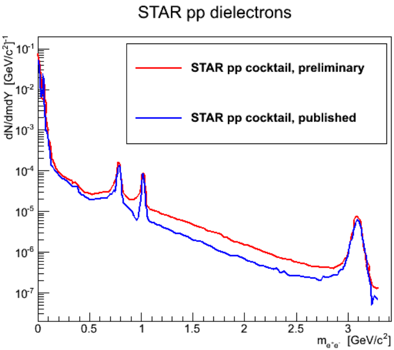
STAR arXiv:1204.1890

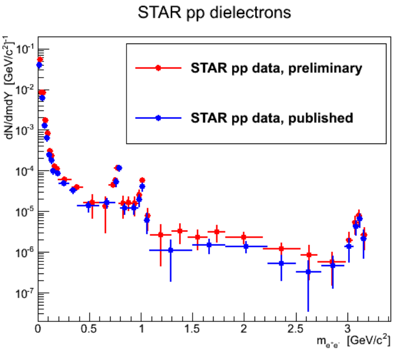




PHENIX cocktail in STAR acceptance
MC@NLO for heavy flavor
resolution not tuned for STAR

STAR charm cross section $\sigma = 920\ \mu b$


STAR pp dielectrons
STAR pp cocktail, preliminary
STAR pp cocktail, published
dN/dmdY [GeV/c2]-1
10-1
10-2
10-3
10-4
10-5
10-6
10-7
0
0.5
1
1.5
2
2.5
3
me+e- [GeV/c2]


STAR pp dielectrons
STAR pp data, preliminary
STAR pp data, published
dN/dmdY [GeV/c2]-1
10-1
10-2
10-3
10-4
10-5
10-6
10-7
0
0.5
1
1.5
2
2.5
3
me+e- [GeV/c2]

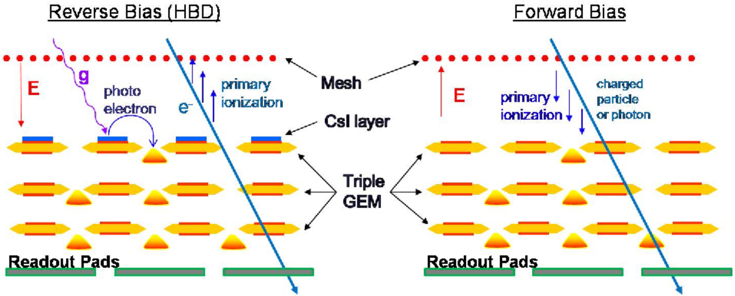
Hadron Blind Detector - the concept

HBD concept

- Windowless Cherenkov detector (L=50cm)
- CF_4 as the radiator and detector gas.
- Proximity focus: detect circular blob and not ring.

Detector Element

- Triple GEM stack with pad readout.
- Reflective *CsI* photocathode evaporated on the top face of top GEM.



HBD concept

- Windowless Cherenkov detector (L=50cm)
- CF_4 as the radiator and detector gas.
- Proximity focus: detect circular blob and not ring.

Detector Element

- Triple GEM stack with pad readout.
- Reflective *CsI* photocathode evaporated on the top face of top GEM.

This scheme exhibits a number of attractive features:

- A large $N_0 \approx 800$ cm^{-1} (ideal detector with no losses), due to a large bandwidth (from ~ 6 eV given by the *CsI* threshold to ~ 11.5 eV given by the CF_4 cut off).
- No photon feedback due to reflective photocathode.
- Hexagonal pads with size (area = 6.2 mm^2) comparable to Cherenkov blob size (10.2 cm^2), that results a single pad hit for hadrons, as compared to 2-3 pads per electron hit.
- Low granularity detector ($\sim$ 1000 pads per central arm acceptance).
- Primary charge of 5-10 e/pad leads to a moderate gain of 5000. This is a crucial advantage for the stable operation of a UV photon detector.

Hadron Blind Detector - the design

The Detector was designed and built at the Weizmann Institute.

- Two identical arms, with each arm equipped with 12 (23×27 cm^2) triple GEM stacks. Each GEM stack is comprised of a mesh electrode, a top gold plated GEM for CsI and two standard *Cu* GEMs, and a pad electrode.
- Kapton foil readout plane: one continuous sheet per side with 1152 hexagonal pads. Also serves as a gas seal, leak rate is 0.12 cc/min.
- Low material budget: total $< 3\%$ X_0 (back plane electronics $\sim 1.5\%$, vessel $\sim 0.92\%$, gas $\sim 0.54\%$).
- $\sim$ 350 gluing operations per arm.